Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Automation Technology

Workgroup: University of Cagliari

University of Cassino and Southern Latio

This document is the Critical Design Review of the technical competence ‘Automation Technology.
Its details the complete design of the pneumatic/electropneumatic test bed..

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1.1 Scope

This document presents the detailed design of the pneumatic/electropneumatic test bed control platform developed in the framework of MISCE project.

The final objective is to use the developed platform in the practical lectures of engineering degrees to contribute to the technical competence:

A1. Automation Technology

which related skills are (see Table I):

Table I. Skills of Automation Technology

S1.1.	To know the main electric/pneumatic and hydraulics elements
S1.2.	To be able to design the functional behavior of the system
S1.3.	To be able to understand the technical documentation of a project/product
S1.4.	To program the functional behavior of the device
S1.5.	To debug the final planned behaviour of the system

1.2 Preliminary definition

This experimental test bed (TB3 version) represents an advanced and more versatile version compared to the TB2, retaining all essential functionalities while improving mobility and enabling quick deployment in various contexts.It is composed of:

- n.1 Siemens PLC of type 1215C;
- n.1 Siemens HMI of type Comfort Basic;
- n.1 Hub switch Simatic;
- n.1 SIMATIC ET 200SP;
- n.1 Ethernet cable for PLC/PC communication;

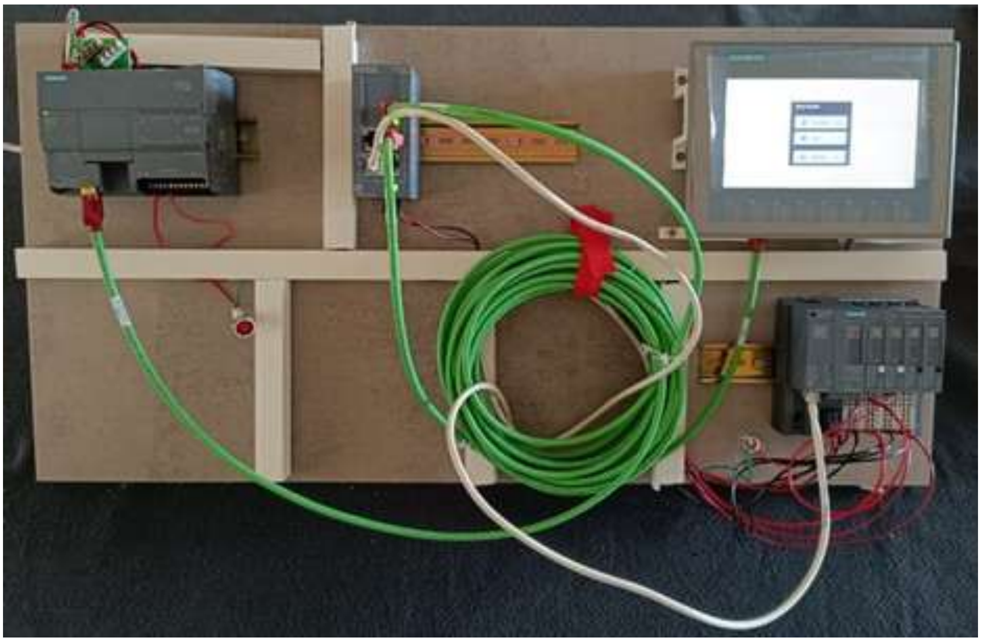


Figure 1 Suitable experimental test bed realized

The application chosen for this test bed allows simulating the system's behavior, particularly the movement of the cylinder, using the software (in this case, Autosim-200), which enables the simulation of movement behavior. The main advantage of this test bed lies in its ability to be used across a wide range of academic activities, offering a very intuitive hands-on opportunity to explore automation technologies.

The primary advantage of this test bed is its capacity to be applied in various applications and educational environments, facilitating a solid understanding of automation and control principles. On the other hand, a major drawback is that certain important features cannot be addressed, as it is a basic actuation system, where the cylinder's return is achieved by means of a spring return.

1.3 Technical requirements

The main advantage of this test bed is its versatility, allowing it to be widely used across different academic activities. Furthermore, the behavior of the cylinder is well-understood and easy to replicate, providing a highly illustrative way to introduce all aspects of automation technology.

1.3.1 Actuation of a single acting pneumatic cylinder

The actuation of the single effect pneumatic cylinder is well-known on teaching activities related to automation technology It consists of a single effect pneumatic cylinder, a 5/2 (five ways, two positions) electro-pneumatic valve with pneumatic actuation and a 3/2 (three ways, two positions) electro-pneumatic valve with mechanical actuation. The movement of the pneumatic cylinder can be controlled also by means of one button or via a PLC (see Figure 2).

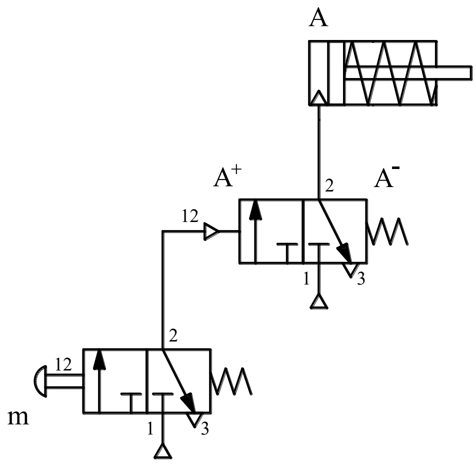


Figure 2. Actuation of single acting pneumatic cylinder

The main advantage of this test bed is related to the possibility to be used widely in different academic activities. In addition, the behaviour of the cylinder is well-know and easy to be achieved and offers a very illustrative way to introduce in all the skills of automation technology.

List of components used:

n.1 Single-acting cylinder;
n.1 Push button (3/2 unistable valve with manual actuation);
n.1 3/2 unistable pneumatically operated power valve.

Functional test:

 By pressing the start button m, the control signal A+ is activated, with the consequent release of the piston of cylinder A;

 when the start button m is released, the control signal A− is activated, with the consequent retraction of the piston of cylinder A. The activation of the control signal A− is determined by the presence of the return spring, with consequent emptying of the rear chamber of the cylinder.

1.3.2 Actuation of a double effect pneumatic cylinder

The actuation of the double effect pneumatic cylinder is well-known on teaching activities related to automation technology . It consists of a double effect pneumatic cylinder, a 5/2 (five ways, two positions) electro-pneumatic valve with electric actuation and a two electric push button. The movement of the pneumatic cylinder can be controlled by means of two button or via a PLC. The control objective of this platform is to control the position of the ball over the beam (see Figure 3).

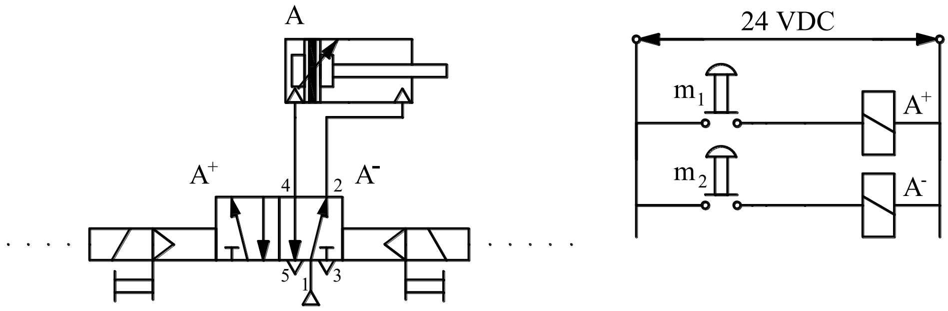


Figure 3. Double effect pneumatic cylinder

This device shall also include the electronics part and the control equipment to command the behaviour of the cylinder by means of electronic board (e. g. Arduino, Raspberry, PLC etc.).

This exercises complements the pneumatic/electropneumatic test bed adding a more functionality in a basic control approach.

List of components used:

- n.1 Double-acting cylinder;
- n.1 5/2 bistable power solenoid valve with pneumatic pilot;
- n.2 m_1 and m_2 electric buttons.

Functional test:

 By pressing and releasing the start button m_1, the control signal A^+ is activated and the piston of cylinder A comes out;

 By pressing the m_2 start button, the control signal A^- is activated and the piston of cylinder A is retracted.

1.3.3 Diagram of Movement-Phase

In order to create a suitable “Movement-Phase” displacement, by using the previous reported experimental platform, will be possible to create all type of required/desired movement/phase diagram. The control objective is to create all possible combination of movement of the cylinder by mean of the experimental/Numerical (digital Twin) Platform (see Figure 4).

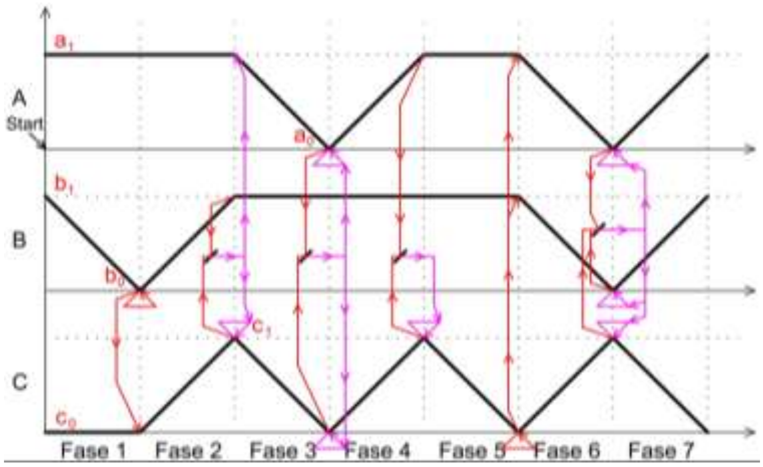


Figure 4. Generation of a suitable “Movement-Phase” displacement

This experimental platform complements the aforementioned by adding a more complex capability.

Using the same hardware set-up it is possible to generate different cycles. It is important to note that compared to the previous two cases, there is no change in the pneumatic and electrical connections; In fact, the only thing that varies is the program downloaded to the controller's memory.

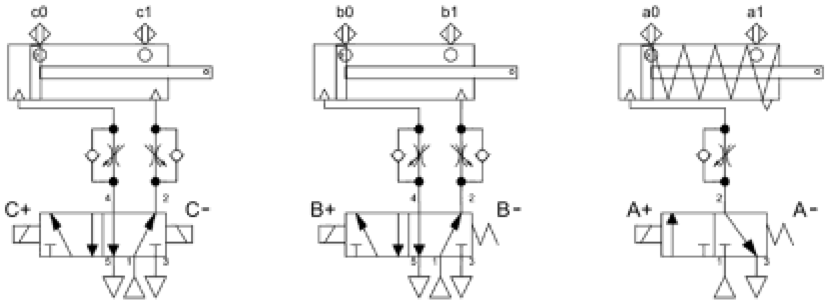


Figure 5. Electro pneumatic connection (physical connection required)

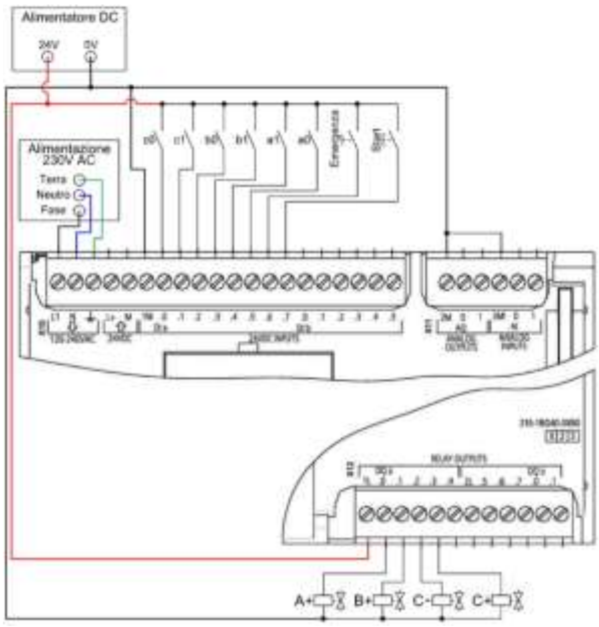


Figure 6. Circuit diagram

The following table lists the variables used within the automation software, indicating their data type, address, and functional description. It includes both physical (input/output) and virtual/internal signals, used for cycle control, phase management, valve command and consent, and system status monitoring:

Table II. Command/Consent Matches with Variables Used in the and Virtual Inputs/Outputs and Functional Roles

Name	Data type	Address	Comment
FC a0	Bool	%I0.5	Physical input
FC a1	Bool	%I0.4	Physical input
FC b0	Bool	%I0.2	Physical input
FC b1	Bool	%I0.3	Physical input
FC c0	Bool	%I0.0	Physical input
FC c1	Bool	%I0.1	Physical input
FC a0 Int	Int	%MW80	Defined to achieve the trend
FC a1 Int	Int	%MW70	Defined to achieve the trend
FC b0 Int	Int	%MW60	Defined to achieve the trend
FC b1 Int	Int	%MW50	Defined to achieve the trend
FC c0 Int	Int	%MW40	Defined to achieve the trend
FC c1 Int	Int	%MW30	Defined to achieve the trend
Start physical	Bool	%I0.7	Physical input
Start from HMI	Bool	%M0.2	Virtual input
Emergency	Bool	%I0.6	Physical input
A+	Bool	%Q0.0	Physical output (3/2 valve)
B+	Bool	%Q0.1	Physical output (5/2 valve)
C-	Bool	%Q0.2	Physical output (5/2 valve)
C+	Bool	%Q0.3	Physical output (5/2 valve)
Emergency reset 1_0	Bool	%M0.1	Virtual input for 7-phase cycle
Memory LED 1_0	Bool	%M5.6	Virtual output for 7-phase cycle
Counter	Int	%MW2	CV current count value
Memory Counter	Bool	%M1.3	Internal counter variable
Data recipes	Int	%MW20	Ensures selection among multiple recipes
ERR	Int	%MW250	Value of return WWW instruction
Memory 1_0	Bool	%M0.4	Initial configuration cycle 7 phases
Memory 1_1	Bool	%M0.5	Phase 1 cycle 7 phases
Memory 1_2	Bool	%M0.6	Phase 2 cycle 7 phases
Memory 1_3	Bool	%M0.7	Phase 3 cycle 7 phases
Memory 1_4	Bool	%M1.0	Phase 4 cycle 7 phases
Memory 1_5	Bool	%M1.1	Phase 5 cycle 7 phases
Memory 1_6	Bool	%M1.2	Phase 6 cycle 7 phases

2 Hardware Design

The hardware design includes some functional parts that can be easily acquire in the market.

2.1 Functional Parts

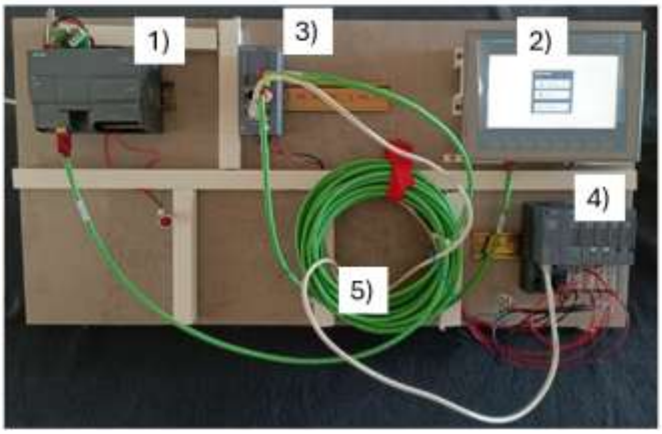
The hardware design includes functional components that are easily available and accessible for educational purposes. In this case, the following functional elements have been selected:

- n.1 Siemens PLC of type 1215C;
- n.1 Siemens HMI of type Comfort Basic;
- n.1 Hub switch Simatic;
- n.1 SIMATIC ET 200SP;
- n.1 Ethernet cable for PLC/PC communication;

As a result, three experimental activities and a digital twin numerical activity have been developed. These activities range from the basic control of a pneumatic actuator to the management of more complex system operations.

2.2 Mechanical Design

The hardware design includes functional components that are easily available and accessible for educational purposes. In this case, the following functional elements have been selected:



1. n.1 Siemens PLC of type 1215C
2. n.1 Siemens HMI of type Comfort Basic
3. n.1 Hub switch Simatic
4. n.1 SIMATIC ET 200SP
5. n.2 Ethernet cable for PLC/PC communication;

Figure 7. Test bed scheme

3 Software Design

The software has been designed to be usable by any user (professors/students). This type of software will require the license, or will be possible to use for a limited time to use the trial version.

In this way, the PLC S71200 has been programmed using its TIA Portal Software, https://www.siemens.com)
Figure 7 illustrates the test-bed architecture.

3.1 Ladder Software

The Ladder program has been designed and documented in the following figures, which represent the cycle divided into 7 phases.

The code of the Ladder software is available, under demand, in MISCE project webpage.

With this test-bed, only the PLC’s LED can be operated, no pneumatic actuators are used for this application.